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AN ELECTRONIC AID FOR AIRCRAFT TRACKING AND INTERCEPTION

NAVAL RESEARCH LABORATORY

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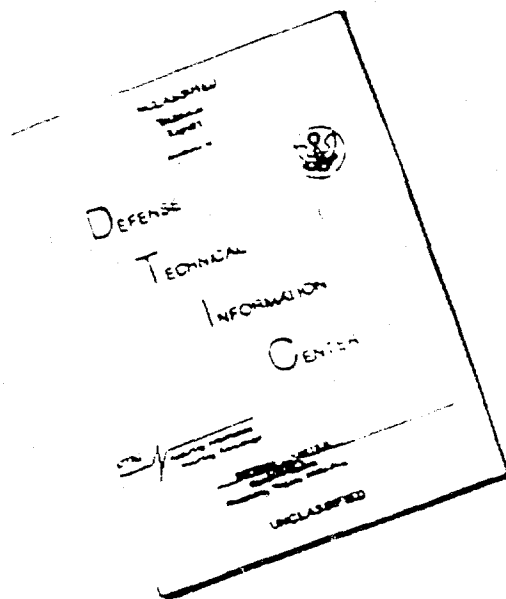
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AN ELECTRONIC AID FOR AIRCRAFT TRACKING AND INTERCEPTION

H. G. Paine

27 April 1950

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CONTENTS

ABSTRACT

A method is described of obtaining and processing electrical target data for the interception of high-speed aircraft. The display on a conventional radar indicator is used as the source of data. A simple method of displaying and processing the data to obtain interceptor course directions is presented. The electrical data obtained by the pick-off and tracking devices could also be used either to speed the processes in a manual fighter direction system or to feed an automatic electronic course computer of the type considered in the Automatic Aircraft Intercept Control System. A means is provided in the tracking device for correction of target parallax between ships operating in a task force, so that correct target reporting to a net could be maintained under conditions of a fixed grid, a moving grid, or when the reporting ship was moving with respect to a grid. Laboratory models of some of the components have been constructed and are undergoing tests.

PROBLEM STATUS

This is an interim report on the AAICS study being conducted at the Laboratory. Work is continuing on the problem.

AUTHORIZATION

Problem R07-25R
NR 507-250

AN ELECTRONIC AID FOR AIRCRAFT TRACKING AND INTERCEPTION

INTRODUCTION

The present state of analysis and development of the AAICS[1] problem indicates that it may be several years before the system is ready for adoption by the Navy. The automatic tracking device contemplated for AAICS requires considerable fundamental research, and this aspect undoubtedly will delay production of the system beyond the time required for the computer and other components.[2] The automatic tracking device also threatens to be the bottleneck in the raid-handling capacity of AAICS.

The fighter direction system in use in World War II has, through dint of experience, training, and skill of operators, reached a high degree of proficiency. When used with a grid in connection with a controlled defense net, as in recent OpDevFor exercises,[3] it has useful capabilities in controlling fairly high-speed aircraft interceptions. However, the system suffers from lack of aids to manual operations and from communication difficulties which stem from the nature and volume of oral data it is necessary to handle.

NRL has been concerned with high-speed aircraft intercept control and detection problems for some time. To fill the apparent need in both of the above systems, an electronically-aided manual tracking system has been devised and is under development at the Laboratory. It is intended to accomplish the following:

1. Provide an interim method of tracking for AAICS that will make earlier realization of that system possible.

2. Provide a source and type of data that will speed the processes involved in either manually plotted close control or in broadcast control.

3. When used in conjunction with an automatic plotting board and a relatively simple linkage computer, permit the realization of a complete and semi-automatic aircraft intercept control system.

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[1] "Automatic Aircraft Intercept Control System Study," S. Riccobono, NRL Secret Report R-3342, 30 August 1948.

[2] "Two-Dimensional Simulation of the Automatic Aircraft Intercept Control System," H. G. Paine, NRL Secret Report R-3617, 26 January 1950.

[3] Third Partial Report on Project OP/V42/S67-5 (Revised) entitled, "Procedures for Shipboard Detection, Control and Interception of High Speed, High Altitude Airplanes," 7 Nov. 1949, Secret.

The salient features of the system, the subject of this report, are:

1. Greater speed of the PPI operator in determining position,
    speed, and course of targets than possible with the present
    standard method.

2. Reporting of the operator is automatic and electrical instead
    of oral.

3. A continuous report is given of present position, speed, and
    course of each target being tracked.

4. The electrical data can be displayed by meter-type indicators
    at all desirable places aboard ship.

5. Data can be relayed to other ships in the controlled defense
    net, to be used there.

6. The position data are given in rectangular coordinates,
    readily adapted to a grid system of defense.

7. Each ship's coordinate offset from an arbitrarily chosen origin
    within the grid could easily be introduced into the data reported
    by the ship, so that each ship would report its data to the net on
    coordinates common to all.

8. Correct target reporting to a net could be maintained under con-
    ditions of a fixed grid, a moving grid, or when the reporting ship
    was moving with respect to the grid.

There are four principal parts of the system envisaged:

1. Data Pick-Off Unit

2. Tracking Integrators

3. Automatic Display Boards

4. Simple Linkage-Type Course Computer

When used together, they form the basis for a semi-automatic intercept-control system,
or when used separately, they would be valuable aids to existing intercept control systems.

The parts are shown arranged into a working system in Figure 1. This arrangement
forms the semi-automatic intercept-control system. If the electronic course computers of
AAICS were substituted for the automatic plotting boards shown in Figure 1, an interim
AAICS would be formed that would serve until Track-While-Scan was developed and ready
for use. The third possible arrangement consists of feeding the continuous position data
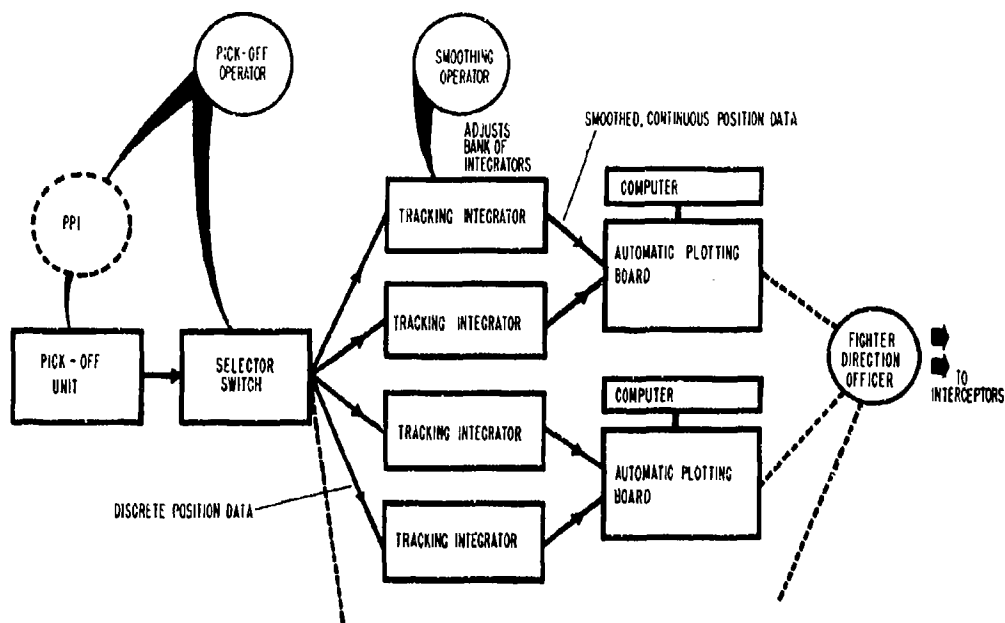(output of tracking integrators) to a manual plotter in an improved manual fighter direction
system.

Figure 1 - Arrangement of units into a working system

DESCRIPTION OF UNITS

The drawings and descriptions of the units are here given to illustrate the principle and ideas involved and should not be construed as an exact definition of the finished units. Further development work of course will be necessary.

The plan for the method under development (Figure 1) makes use of a team of two operators to perform the work of determining the target's position,* speed, and course. One operator, seated at a model VK or similar indicator, uses a pick-off unit to obtain only the position of the target. The operation is repeated by him on successive targets as rapidly as possible. If the design of the pick-off unit conforms to operational and psychological requirements (i.e., lightness of movement and position of pointer above the PPI surface), the rate of pick-off and the accuracy of pointer placement will both be quite high.

The tracking integrator units are electronic integrators of the analogue computer type. They are used to obtain a continuous coordinate output. They place a requirement on the pick-off unit that it deliver discrete postion data in X and Y as scaled d-c voltages. A pair of integrators with the necessary controls is used for each target.

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* Target position as used here is the X and Y coordinate position only. Altitude information will require a separate data device and possibly a third operator, depending on the nature of the height-finding equipment used.

The second operator (designated "smoothing operator") attends a bank of integrators. He adjusts the controls of each pair of integrators to produce an output conforming to the average of the discrete position data provided by the pick-off unit. The operation of adjusting the controls determines the speed and course of the target.

The two operators, plus the necessary electronic aids, would thus perform the function of Track-While-Scan. The continuous electrical data output could be fed directly to the computer of AAICS, or could be relayed to remote points for manual or automatic plotting, where it would be used for display or for fighter direction.

The last two parts of the system, the automatic display boards and the linkage type course computer, are further aids to a manual system. A complete* semi-automatic intercept-control system could be designed around the four units, as illustrated in Figure 1, or the units could be used to modify and improve the existing processes and techniques of the present fighter direction system.

Data Pick-Off Unit

An arrangement meeting the electrical requirements of a pick-off unit is illustrated in Figures 2 and 3. The particular mounting used in Figure 2 shows the principle involved and the physical relationship of the unit to a PPI face. An alternate mechanical arrangement is shown in Figure 4. Both arrangements result in an electrical data origin that coincides with the center of the PPI. A third possible mounting, shown in Figure 5, causes an offset in the origin. This, fortunately, does not introduce complications since correction can be made in the same manner as correction is made for the ship's position with respect to a coded origin on a common grid system. Provision for offset correction is made in the tracking integrators.

The simplicity of a resistance network, unencumbered by auxiliary electronic circuits, recommends the method of data pick-off illustrated in Figures 2 through 5. The requirement of lightness of movement should control the mechanical design of the movable arm assembly. Sine-cosine potentiometers are available commercially with amplitude accuracies within ±0.6 percent and angular accuracies with ±0.5°. In the development of this system, full consideration should be given to other methods of picking off position data (such as a conducting glass overlay) to assure adoption of the method best suited to it.

A systemized procedure of picking off data is necessary for full utilization of the equipment's capabilities. It is necessary that each channel and accompanying equipment be given a name or a number. For purposes of illustration, B-1, B-2, etc.; R-1, etc.; and X-1, X-2, etc., are used here to describe both targets and channels. For example, the B numbers (blue) could be assigned to the friendly planes, the R numbers (red) to enemy raids, and the X numbers to new targets before they have been identified or evaluated. A procedure for picking off data on several targets is illustrated in Figure 6. The operator sits at the radar indicator with his left hand in a position to operate the selector switch and with his right hand holding the position pointer. He works progressively from target to target in a clockwise direction around the PPI. The light movement of the position pointer permits a quick arm movement of the operator to an approximate location of the

---

* The common problems presented by altitude, communication, and data relay are not covered here. Development of the proposed system would of necessity embrace them in accordance with their present line of development.

pointer above the next target. The operator can then rest his hand on the glass overlay and use finger movement for a more precise positioning of the pointer. The pointer, which is equipped to make a crayon or grease mark, is pressed against the glass overlay directly above the target. While the pointer is in position, the left hand operates the selector switch which channels the electrical position data into the correct set of integrators. The grease marks left on the glass form a record of target tracks, as shown in Figure 6. They assist the operator in maintaining continuity of channel selection.
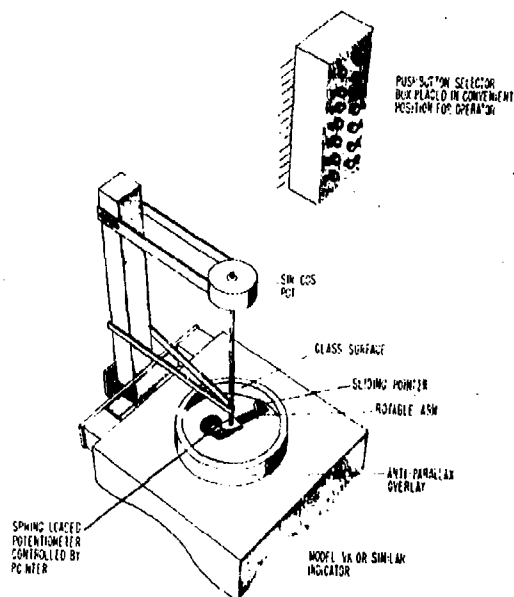
Figure 2 - Pick-off unit
mounted on indicator

Figure 3 - Schematic of
pick-off unit
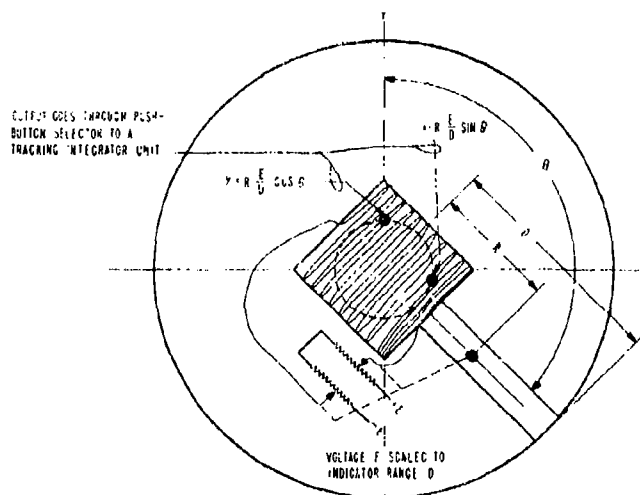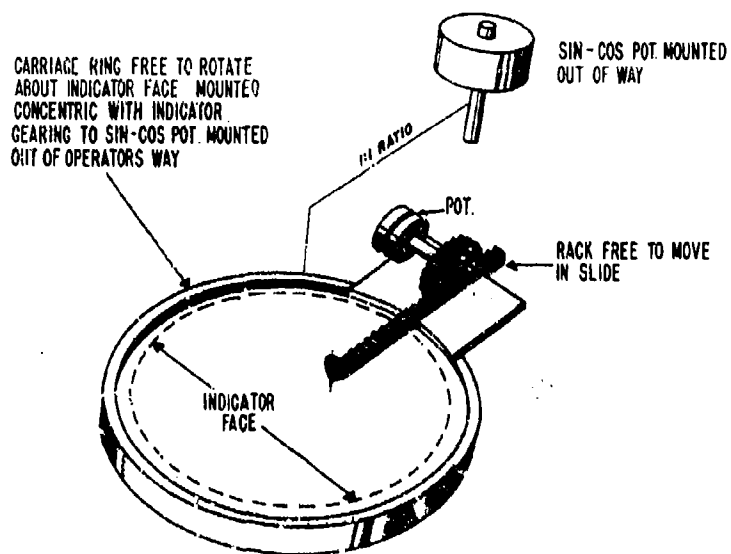
Figure 4 - Schematic of alternate mechanical
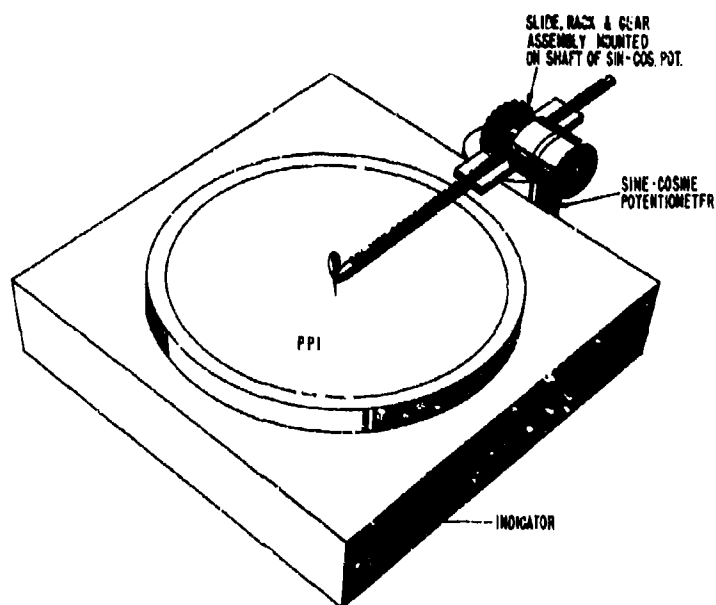arrangement of pick-off unit

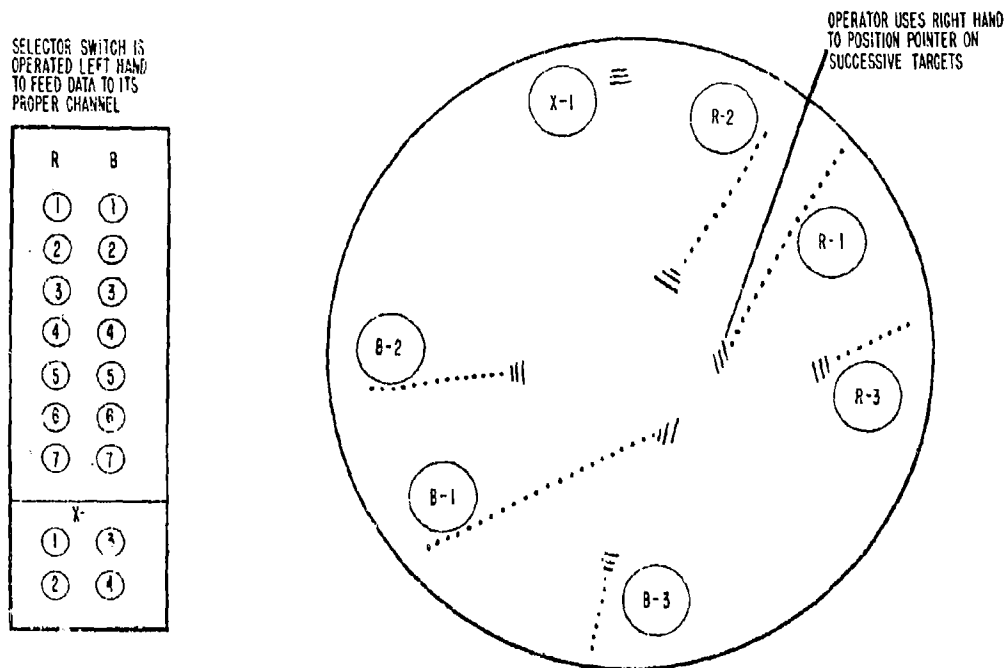Figure 5 - Offset arrangement
of data pick-off unit

Figure 6 - Procedure of data pick-off

When a new target is first observed by the pick-off operator, he positions on it and uses an X number of his own selection. The operator writes the X number on the overlay beside the new track. The X number integrators should be equipped with warning lights to call the evaluation officer's immediate attention to the new target. The pick-off operator continues to track all targets in sequence, including the new target. After identification and evaluation of the new target, the evaluation officer assigns either an R or B number to it. The operator rubs out the X number on the overlay and writes in the R or B number. Thereafter he uses the new channel on the selector switch for this target.

It is expected that the time required for a trained operator to position the pointer on a target and to press the corresponding selector switch would not exceed a three-second average per target. For a concentration of ten targets, the operation of a systemized pick-off scan would require approximately one-half minute. Since the integrators can operate satisfactorily with much longer data intervals than this for straight flying targets, the operator has freedom between pick-off scans to search for new targets or to concentrate on any target known to be maneuvering.

Tracking Integrator Unit

Each of the tracking integrator units required in the system consists of the arrangement shown in Figure 7. Speed and course are set manually by the smoothing operator. The integrators yield a continuous electrical data output (X and Y) shown at the right of Figure 7. Position of the target is fed nonperiodically to the integrators through the
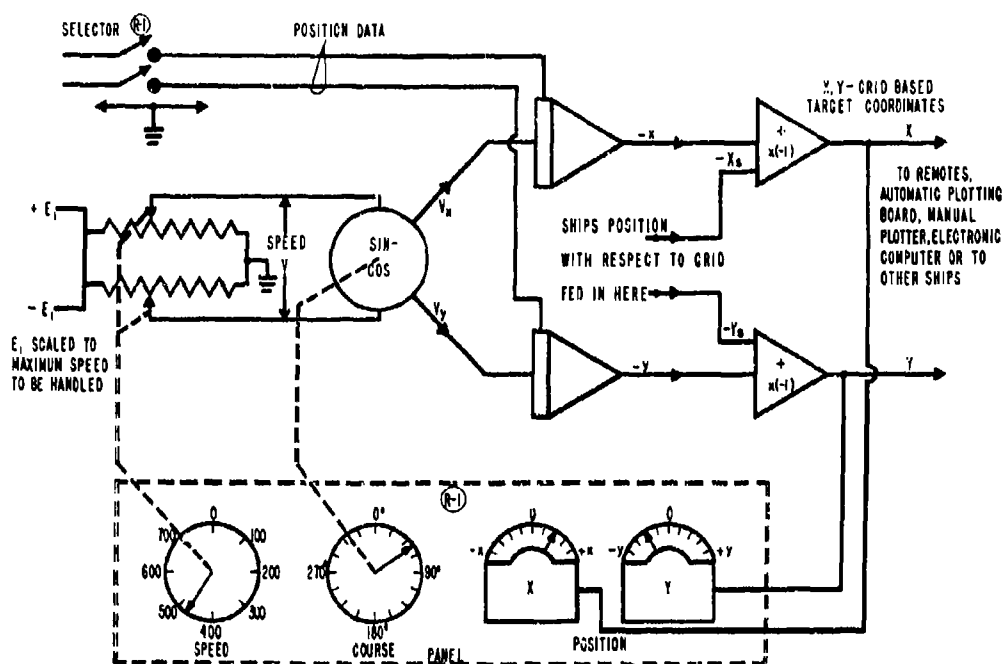
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Figure 7 - Tracking integrator unit

selector switch operated by the pick-off operator. The position of the target as indicated by the output of the tracking integrators may be in slight variance, at any instant, with discrete position data obtained by the pick-off unit, depending on previous smoothing, target movement, and system errors. The circuitry of the tracking integrators provides automatic correction of output to the discrete position values. As a result, the X and Y output is corrected to the target's position each time the pick-off operator pushes the unit's selector button. The nature and degree of correction that occurs is observed and used by the smoothing operator as a criterion for adjustment of the speed and course dials. This adjustment or smoothing of each tracking integrator unit in the required bank of integrators constitutes the entire duty of the smoothing operator.

When automatic display boards (described later) are used to display and record the X and Y output of the tracking integrator units, the degree and sense of position correction is registered automatically with the track of the target. The smoothing operator is afforded a visual indication of the amount and sense of smoothing required. He can work rapidly then from unit to unit and does not have to keep in step with the pick-off operator.

However, when the output of the integrators is not displayed automatically, as in feeding data to the course computer of AAICS or to a manually plotted close control system, other means of determining smoothing are required. This can be done by use of a differential metering circuit (not shown in Figure 7) which will register and remember for a few seconds only, the difference between target position and generated position. The smoothing operator must use this information while available; hence he would have to keep in step with the pick-off operator. Greater teamwork between the operators is necessary in this case, and a warning light on the panel of the integrator unit whose control is ganged to the selector switch would assist the smoothing operator in keeping pace.

In addition to the equipment shown in Figure 7, the shaft positions of the speed and course dials would have to be converted to electrical data for transmission to remote locations and to other ships, along with the X and Y output. Panel room in addition to that shown would need to be provided for display of altitude information and for the differential meters used by the smoothing operator.

The summing amplifiers shown in Figure 7 are included to permit transformation of the coordinate data from axes passing through the ship to axes common to the entire task force. The manner in which axes may be superimposed on a grid system of a task force is shown in Figure 8. The ship's coordinates (X_s and Y_s), which are fed to the summing amplifiers for coordinate transformation, are obtained by modifying the assigned position coordinates (X_a and Y_a) with the excursion coordinates (X_{DR} and Y_{DR}) which are in turn obtained from the dead-reckoning equipment aboard ship. Each ship of the task force can make necessary maneuvers about its assigned position on the grid without introducing errors into the data which it reports to the control net.

The system is readily adaptable to ship movements within a fixed grid and to rapid changes in the coded origin of the common axes; with some additional equipment, it could be adapted to operation on a moving grid.
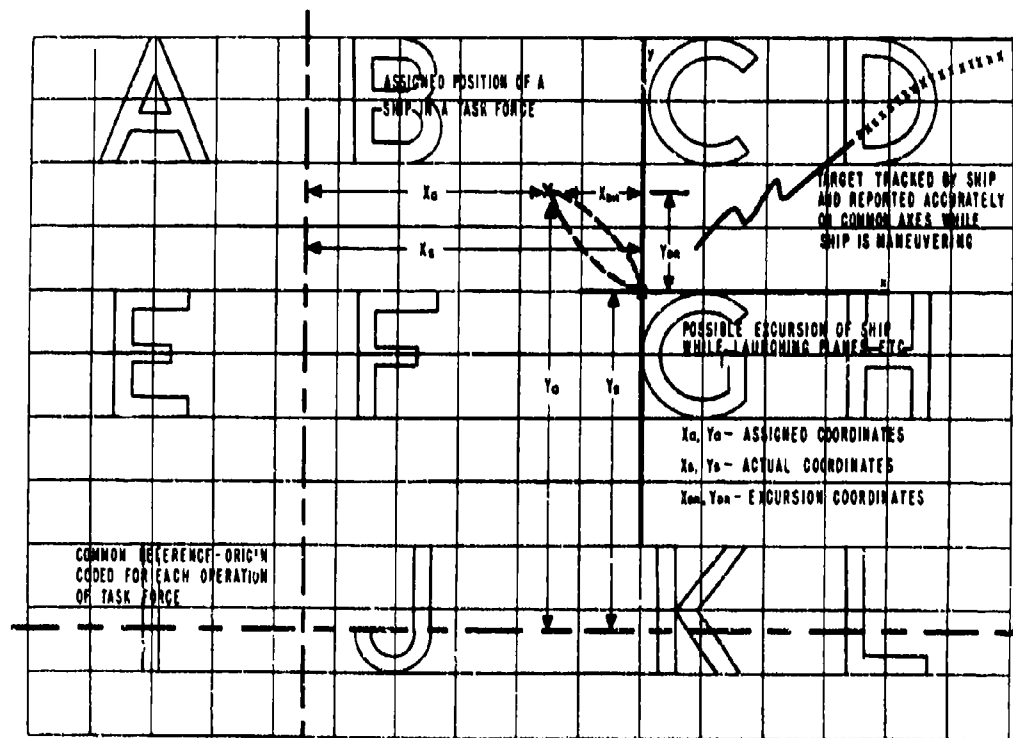

Figure 8 - Relationship of coordinates

Automatic Display Boards

The primary function of the automatic plotting boards would be to display each separate close-controlled interception and to record the interception in its entirety. As a secondary function, the plotting boards would assist the smoothing operator in the performance of his duties and would eliminate the need of differential metering circuits in the tracking integrators.

Figure 9 illustrates the idea of an intercept plotting board. Two servo-positioned carriages are provided on the same board. One would be used for the attacking bomber's track and the other for the track of the fighter assigned to the interception. The paper inserted on the board could be printed with a scaled grid corresponding to the grid used by the task force in its operation. Pertinent information for each operation (such as the origin of common axes, the assigned location of ships in a task force, etc.) could be marked on the sheets by personnel just prior to inserting and aligning the sheets in the boards. A clear picture of each individual interception and its relation to the task force would be presented.
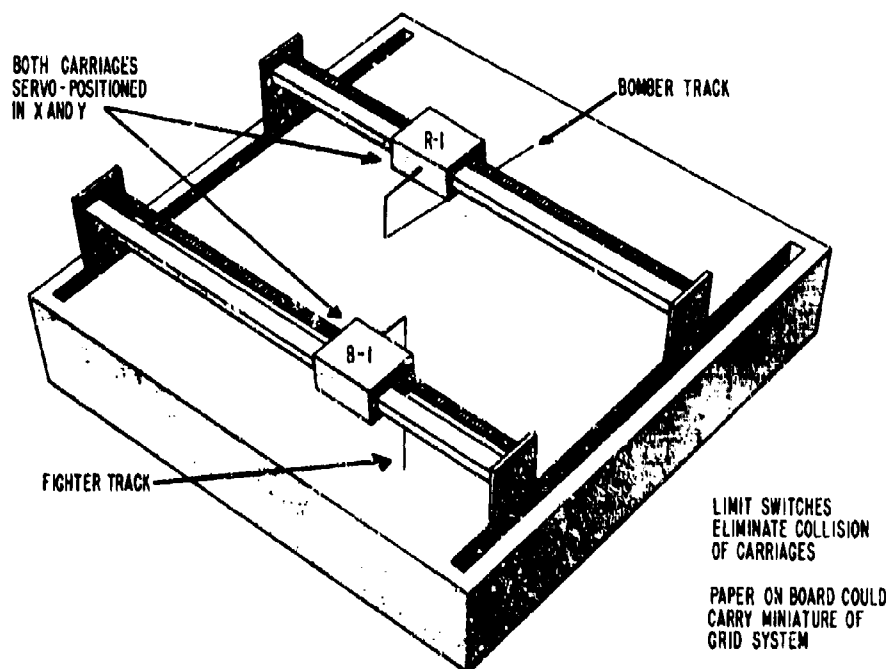
Figure 9 - Intercept plotting board

In the normal procedure, one of the carriages would be assigned to the attacking bomber at the time of identification or evaluation. The carriage chosen would depend on the orientation of the raid with respect to the task force. As soon as the interceptor was airborne and a track had been obtained on it, the second carriage would be assigned to the interceptor. There should be provided with the boards facilities permitting personnel to push a button that would lift the bomber pen and return the bomber carriage to its out-of-the-way position when word was given of tally-ho. This would provide a continuous track

of the fighter across the projected track of the bomber. It would provide a continuous track of the bomber up to a short distance before actual interception. The interceptor carriage could be kept on the fighter track through "kill" and back to base or until turned over to CCA, thus providing complete interceptor surveillance with a permanent record of the action.

To eliminate the possibility of mechanical interference of the carriages through delayed tally-ho or other difficulties, it is proposed to surround both pens with guard bumpers that would automatically return the bomber carriage to its out-of-the-way position when either bumper touched any part of the opposite carriage.

.The number of plotting boards required aboard each ship would equal the saturation limit for close-controlled interceptions plus a reserve for overlapping of control between ships. They could be wall or rack mounted (vertical position) in banks for space saving and for convenient observation. The arrangement of the boards in a bank would serve to show at a glance the number and character of all raids in progress.

Simple Linkage-Type Course Computer

The course direction of the interceptor could be obtained from the plotting boards by the same mental estimation processes used in the present fighter direction system. However, as an aid, the simple linkage-type course computer shown in Figure 10 is suggested. The particular computer illustrated was designed and constructed at NRL. It was tested in connection with a manual plotting board during some intercept simulation studies. The two main arms of the computer are marked with speed scales as shown. At the start of an interception, the bomber and fighter speeds are set on these scales. The fighter direction officer would use the device during an interception as frequently as he deemed necessary to keep the fighter on the correct course. A detailed description of the procedure to follow in using the computer is given under the numbered captions of Figure 10. The computer would be of real aid to either the manually plotted close-control system or to direction based on the automatic plotting boards. Pivot pins would need to be mounted on the carriages of the automatic plotting boards so that the computer could be readily attached.

SUMMARY

The system submitted herein is aimed at filling a definite need in Naval defense for the interval between the present and such future time when more elaborate and automatic systems are available. The nature of the electrical target data in this system is similar to, if not identical to, the form of data likely to be evolved in any future system such as AAICS. This similarity has a distinct advantage in that interim development of data relay links and CIC display devices for use with the subject system could be readily adopted for use with AAICS.

There is a possible future use for this system after the advent of AAICS equipment in the Fleet. At the present time, it seems likely that the long-range radar and T-W-S of AAICS will be installed principally on larger ships. Adequate defense of a task force will require efficient utilization of all ships in the force, particularly those assigned picket duty at the periphery of the task-force area. The subject system could be used on the lighter ships not equipped with AAICS to complete an adequate and efficiently controlled defense net for the task force.

Experimental models of all units of this system, except the intercept plotting board, have been constructed in the Laboratory, and preliminary experiments run on them.

Figure 10 - Plotting board intercept course computer
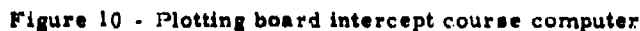
The development of an intercept plotting board should not entail a great deal of difficulty since there are in existence plotting boards of similar character whose designs could be modified or adapted to this application. Figures 11 and 12 show two experimental versions of the pick-off unit. Developmental work will be necessary before the units can be assembled into a working system. Since the principles involved are well known, very little detailed or fundamental research should be necessary. Some research may be necessary, however, when the system is perfected, to devise procedures and techniques for use of the system within a ship, and, when data relay links are available, for the intra-ship coordination of several systems.
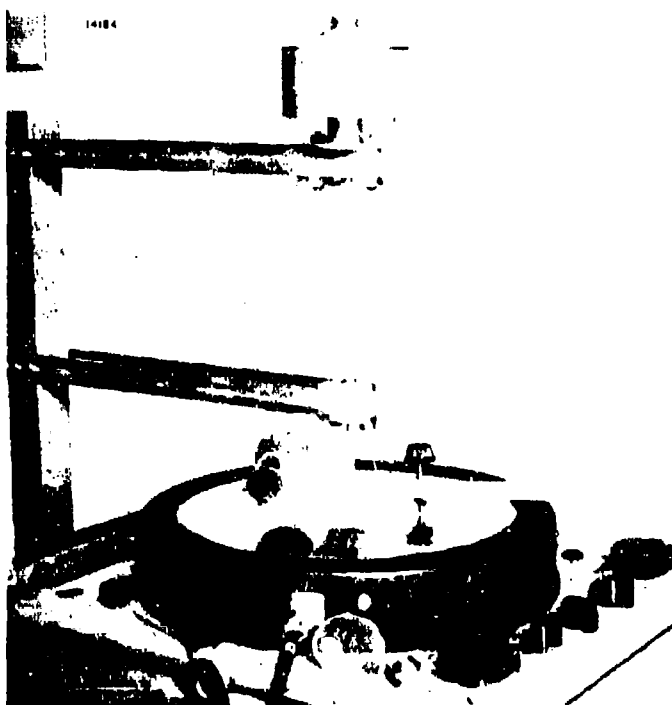
Figure 11 - Experimental
model of pick-off unit
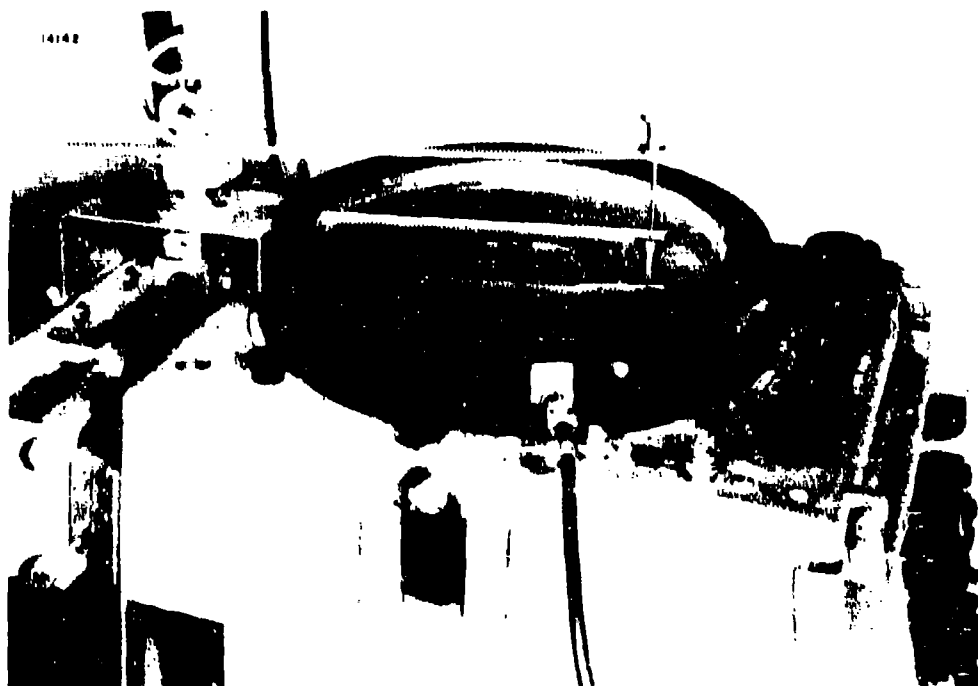
Figure 12 - Experimental model of pick-off unit for offset mounting

* * *

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Naval research laboratory.   Report 3665.
   An electronic aid for aircraft tracking and interception, by H. G. Paine.   Washington, Naval Research Laboratory, April 27, 1950.

13 pp.   illus.   27 cm.

Abstract. A method is described of obtaining and processing electrical target data for the interception of high-speed aircraft. The display on a conventional radar indicator is used as the source of data. A simple method of displaying and processing the data to obtain interceptor course directions is presented. The electrical data obtained by the pick-off and tracking devices could also be used either to speed the processes in a manual fighter direction system or to feed an automatic electronic course computer of the type considered in the Automatic Aircraft Intercept Control System. A means is provided in the tracking device for correction of target parallax between ships operating in a task force, so that correct target reporting to a net could be maintained under conditions of a fixed grid or a moving grid, or when the reporting ship was moving with respect to a grid.

1. Aircraft - location of. 2. Tracking. 3. Radar - intercepting. I. Paine, H. G.

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